$$v^2 = \frac{4A}{\pi k d_o^2 s_{ao}^{\frac{2}{3}}} \sqrt[3]{\frac{1}{s_a}},$$

for which we can also write,

$$v^2 = \frac{4A}{\pi k d_o^2 s_{ao}} \sqrt[3]{\frac{s_{ao}}{s_a}}.$$

But $v^2_0 = \frac{4A}{\pi k d^2_o s_{ao}}$ is the vertical velocity of ascent, corresponding to a definite density s_{ao} of the air, and to the corresponding buoyancy appropriate to it. With this notation we obtain

$$v^2 = v_0^2 \sqrt[3]{\frac{s_{ao}}{s_a}} \quad \text{or} \quad v = v_0 \sqrt[6]{\frac{s_{ao}}{s_a}},$$

or approximately

$$v = v_o \sqrt[6]{\frac{p_o}{p}}.$$

Hence, the velocities of ascent are inversely as the 6th root of the corresponding air pressures.

According to the preceding the maximum height that an elastic balloon can attain depends not at all on the size of the balloon, the nature of the gas with which it is filled, etc., but only upon the capacity of the material for elastic expansion. The greater the volume of the elastic covering can become without bursting, so much the greater the height. The size of the balloon is only to be considered in so far as that it must be sufficient, without being too greatly expanded, to give the buoyancy necessary in order to raise the balloon and the instruments. The balloons used heretofore, as furnished by the Continental Gummifabrik in Hanover, can easily stretch to double their diameter without bursting. Therefore, the height they will attain is about 18,000 meters.

The following table will be of use in the employment of india rubber balloons. The first column shows the density of the air, the second the altitude, the third the ratio $\frac{d}{d_o}$, the fourth the ratio $\frac{v}{v_0}$, the fifth the ratio of the ventilation, or of the mass of air flowing past the balloon.

TABLE 2.

Density of the air.	Altitude.	d/d_o	v/v_o	q/q_o	Density of the air.	Altitude.	d/d_o	v/v_o	q/q_o
	Meters.					*Meters.*			
1.25	20	1.00	1.00	1.00	0.50	8500	1.36	1.16	0.46
1.19	500	1.02	1.01	0.96	0.47	9000	1.39	1.18	0.44
1.13	1000	1.04	1.02	0.92	0.45	9500	1.41	1.19	0.43
1.07	1500	1.05	1.03	0.88	0.42	10000	1.44	1.20	0.41
1.01	2000	1.07	1.04	0.84	0.37	11000	1.49	1.22	0.36
0.96	2500	1.09	1.04	0.80	0.32	12000	1.57	1.25	0.32
0.91	3000	1.11	1.05	0.77	0.27	13000	1.67	1.29	0.28
0.87	3500	1.13	1.06	0.74	0.23	14000	1.76	1.33	0.25
0.82	4000	1.15	1.07	0.70	0.19	15000	1.87	1.36	0.21
0.78	4500	1.17	1.08	0.67	0.18	16000	1.91	1.38	0.20
0.74	5000	1.19	1.09	0.65	0.16	17000	1.99	1.41	0.18
0.70	5500	1.21	1.10	0.62	0.14	18000	2.07	1.44	0.16
0.66	6000	1.24	1.11	0.58	0.12	19000	2.18	1.48	0.14
0.63	6500	1.26	1.12	0.56	0.11	20000	2.25	1.50	0.13
0.59	7000	1.29	1.13	0.54	0.08	22000	2.27	1.51	0.10
0.56	7500	1.31	1.14	0.51	0.06	24000	2.28	1.51	0.08
0.53	8000	1.33	1.15	0.49					

Table 2 shows that very considerable heights can be attained with closed rubber balloons if they can expand to more than twice their original diameter. In practise, however, the misfortune is often noticed that the envelopes in expanding develope small holes through which the gas rapidly escapes. In such cases it happens that the balloons do not explode although the altitudes that they can attain under such circumstances are very considerable, such as 12,000–13,000 meters.

However, in such cases we lose one advantage which Assmann more especially has pointed out, namely, that a closed balloon ascends with increasing velocity and does not maintain any position of equilibrium. The leaky balloon floats for some time at the highest altitude, so that the thermometers have no proper ventilation, and then descends too slowly. On this account, it would be well in all cases to give the balloon, by a strong distension in the beginning, a more than sufficient upward impulse, so that in the first place it will certainly explode, and in the second place be sufficiently ventilated. The fact that the velocity varies inversely as the 6th root of the pressure, therefore, increases somewhat slowly, makes a great velocity in the beginning particularly desirable.

If we take the product of the vertical velocity by the density of the air as the measure of the ventilation, then in the vicinity of the surface of the earth and at 4 meters per second this will be 5, but at an altitude of 20,000 meters where the velocity, according to our table, has risen to 6 meters per second, the ventilation will be 0.65. The latter figure is certainly no longer sufficient to protect even well sheltered thermometers against radiation. According to our experience we must attain a value of 1. This figure, however, requires an initial ascensional velocity of 5.7 meters per second, a velocity that can easily be given to rubber balloons. For still greater maximum altitudes a still greater initial velocity must be given. For these ascending velocities, however, one must use very sensitive instruments and not sluggish thermometers. In Strasburg, since the introduction of the closed rubber balloons, we have with great success used the tubular thermometer, described by me in the protocol of the Conference of the International Commission for scientific balloon ascensions at Berlin. This thermometer has a sensitiveness more than sufficient to enable it to record properly during the above desired velocity of ascension; it also possesses the lightness (weighing with the clock and protecting case 560 grams) necessary to make it possible to rise with rubber balloons of 1.50 meters diameter.

The further advantages possessed by the rubber balloons have been so fully described by the inventor, Dr. Assmann, in the protocol to the above-mentioned conference that I do not need to go into any further details. I will only close with the wish that they may be used frequently and with good results.

DETAILED CLOUD OBSERVATIONS. A PROGRESSIVE PHASE IN WEATHER FORECASTING.

By Rev. FREDERICK L. ODENBACH, S. J., dated January 8, 1904, Meteorological Observatory of St. Ignatius College, Cleveland, Ohio.

Isobars have formed the stepping stones on which weather forecasting has mounted to take its place among the sciences. The daily survey of the atmosphere and the publication of weather maps have enabled meteorologists to bring out these facts; that the *nature* of our weather depends on the configuration of isobaric lines, but its *intensity* on their gradient. With these two principles to start with, a few decades have sufficed to develop a method of forecasting that has met with very encouraging results and has been of great value to most varied classes of interests. But, in spite of these successes, there is a prevailing conviction among forecasters that in the face of great difficulties progress, at the present time, is checked.

In spite of telegraphic systems and the map material at our disposal twice each day, certain obstacles bar our further advance which may be summed up as follows:

1. We miss many an important detail in the map.
2. We are often left ignorant of the sudden formation or dissolution of highs and lows, or of changes in their intensity.
3. The irregular progress of some isobaric systems can not be detected on, or inferred from, even the most perfect map. The initiated will hardly call for a proof of this statement. But how are we to mend our condition? A thousand stations would hardly bring out the necessary detail in a map; and, even if they did, the changes in atmospheric conditions would

make the map unreliable for the hours which intervene between the morning and the evening report. Moreover, a change may occur even during the short space of time that elapses between the observations and the compilation or utilization of the map. Continuous telemeteorology might offer an efficient remedy, but that must be considered, for the present at least, as a scientific utopian dream.

Much diligence and eminent talent are being brought to bear on meteorological problems. There is great activity everywhere; the atmosphere is sounded by means of kites and balloons, data are collected and collated, but the results apparently answer the "how" and the "wherefore" of the theorist, rather than the pleading "what" and "when" of the solitary forecaster, to whom the public looks for definite information, and who stands or falls by his personal wits.

It is fair, therefore, to say that the weather map alone, though an indispensable help, will not advance the science of forecasting much beyond its present stage. We have read everything out of the map which seems contained in it: still we are often at a loss, often at fault. It will be wise, therefore, to look elsewhere in the hope of striking a new trail, which will advance us another step such as that taken when we began to consider the configuration of isobars.

For quite a run of years, while constantly and diligently observing the clouds [as they come and go in their varied forms and directions, their different colors and speeds] the conviction has firmly taken hold of me that they have more to tell than we have hitherto supposed. I believe that a systematic and detailed study of the clouds will, to say the least, advance us one more step in the science of forecasting. Possibly that step may be much more progressive than we can or dare imagine at the present moment.

This conviction is chiefly based on my personal experience; yet it seems that any one who considers the nature of clouds ought to come to the same conclusion. Clouds are the immediate product of weather conditions, not indeed directly overhead, but at some distance from us. We have here a relation of cause and effect. Similar causes are followed by similar effects. The combination of weather elements is varied, but any variation here will produce a corresponding change in the effect, namely in the clouds. I would, therefore, consider cloud as an index; as a hieroglyphic language of the weather, if you will, written against the blue sky. If they are unintelligible to us it is not nature's fault; she never writes in meaningless scrawls.

What attempt has thus far been made to decipher this script? We have picked out ten or a dozen cloud forms and observed these in a way. But is it reasonable to expect that the ever changing weather in its endless variety can be depicted by means of 10 simple signs? Abercromby seems to me to contradict himself, when he writes within the space of three pages the two following passages. After referring to his catalogue of 10 cloud forms, he says:[1]

> Almost all the smaller varieties are so rare or transient that for practical purposes they be neglected, but if, on the contrary, the 10 main words are restricted to the forms of cloud we have described under them * * * then the author can say, from experience of cloud observation in all longitudes and in latitudes ranging from 72° north to 55° south, that 90 per cent of skies in every part of the world can be sufficiently accurately defined by these 10 words.

Two pages further on he remarks:[2]

> We have seen that there is a fine-weather cumulus, as well as cumulonimbus, a fine-weather, as well as a dangerous cirrus, while fleecy clouds have not the same import in London as on the equator. In practise, the good and bad forms can rarely be mistaken, but sometimes very difficult cases arise. Clouds, in fact, tell us by their appearance, what might be written in words, that more or less damp air is rising or falling under certain conditions of upper and lower wind currents; the significance must be judged by the surroundings and antecedents, just as the sense of many words can only be judged by the context.

We must remark, that there is nothing so small in nature that we may neglect it with impunity. It may be possible with these 10 forms to define the general appearance of 90 per cent of skies; but 95 per cent of observers would be able to conclude precious little about the weather conditions under skies so vaguely described. Then the certain conditions, the surroundings and antecedents, which are written in the clouds—these are the very things we wish to get at, and I doubt seriously if 10 words are sufficient to describe the great number of combinations formed by weather factors, whose existence must be and is expressed in cloud language.

Here, then, is evidently an opportunity for progress. Cloud language and cloud dialect seem to promise the much coveted aid, and perchance this language will be as serviceable as is the incomparable barometer.

If the sky were as intelligible to us as is the daily weather map with its isobars, isotherms, wind direction, and velocity, we could follow weather changes with something like the certainty of a skilled physician watching the symptoms of his patient toward recovery or total collapse. This knowledge, and the facility in using it, can be acquired only with patient and systematic labor. We must study the letters, the words, and phrases of cloud language. In the beginning, no doubt, it will be a task no less arduous than that undertaken by those who first deciphered hieroglyphic inscriptions, but it seems no less promising.

Some progress has already been made along these lines. We have the 10 cloud forms, laid as a foundation by the international cloud committee. Blue Hill, Upsala, and several other observatories have done very efficient work. Still these are isolated attempts, and it is to be feared that there are too few who are really interested in this important subject, owing to its primitive condition, and perhaps to a lack of methodical directions in its pursuit.

For these reasons I have attempted to put the subject in the light in which I view it, and will give the classification used at the Meteorological Observatory of St. Ignatius College, together with some of our methods, reserving the finer details for subsequent articles if the subject should prove interesting to the readers of the REVIEW.

Many will, no doubt, be shocked by our elaborate catalogue of cloud varieties, but it has already been stated that the simple, though fundamental divisions of the International Cloud Committee can do nothing to advance the science of forecasting. These are a part of the A, B, C of cloud language, and will remain so unless we progress.

Abercromby has correctly stated the practical object of cloud study when he says:[3]

> The foundation of all modern cloud knowledge turns round the relation of cloud forms to shapes of isobars.

Now, there are more than 10 staple forms of clouds, each of which has its own peculiar significance, because it is the product of a peculiar combination of weather factors, and we can not, therefore, neglect any one of them without running the risk of leaving a very serious gap in the systematic knowledge we are anxious to acquire. It will be our task to recognize and record all staple cloud forms, together with the atmospheric conditions that precede, accompany, or follow them. If I am told that cirrus preceded a certain storm, I know very little, since I have many forms of cirrus in mind, and it would interest me to know precisely which form was observed in that particular case, and, more than this, there are many interesting, intelligible points about every cloud that demand recognition and interpretation. It is evident, therefore, that cloud language and cloud study can not be so simple as seems to have been taken for granted in all instructions to observers; one will prove as complicated as the other.

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[1] Weather, p. 118.
[2] Ibid, p. 120.
[3] Weather, p. 122.

In setting forth our system of species and varieties I have added no definitions, as the names, for all present purposes, are sufficiently self-explanatory. It has been my endeavor to make the classification as rational and exhaustive as possible.

Hence, principles of division were assumed, which will cover the whole field, and are so simple and elastic that they may be applied to the most peculiar climate or sky. In judging of the detail in classification, I would caution the reader to remember that this is the particular dialect of cloud language as it is found in and around Cleveland, Ohio. How it would work in other regions I know not, though it occurs to me that several good exact monographs for special localities could later on easily be reduced to a universally practical system.

Dr. Hann remarks in a note to his chapter on cloud classification:[4]

> The inexpedience of attempts to classify clouds on purely genetic and physical principles, i. e., without a morphological basis, has been insisted on repeatedly.

The reasons are plain. Our present knowledge of the causes of different cloud forms is too limited to establish a natural classification. Even if we understood the genesis of cloud forms, the human eye and the cloud forms will always remain the only factors on which the observer must rely for his indications of the coming weather.

What is desired, therefore, is an exhaustive, or, at least, an expansive system of cloud forms, even if it be artificial, around the elements of which we may group the results of our observations. Our classification of clouds will naturally follow the same laws and pass through the same stages as did the zoological and botanical systems of Linnæus.

CLOUD CLASSIFICATION.

Grand division (principle of division—the nature or material of the cloud).

Class I. Ice clouds: Crystals.
Class II. Watery clouds: Solid water particles.

Subdivision into families (principle of division—the extension of the cloud).

Family I. (The line.) Cirrus: Fiber clouds.
Family II. (The surface.) Stratus: Layer clouds.
Family III. (The solid.) Cumulus: Lump clouds.

With these five elements, obtained by dividing according to nature and extension, we have five genera of clouds, a division which is exhaustive and comes very near to that of Howard.

The five genera.

1. Cirrus.
2. Cirro-stratus.
3. Cirro-cumulus.
4. Stratus. (*a*) Alto-stratus.
   (*b*) Low stratus.
5. Cumulus. (*a*) Alto-cumulus.
   (*b*) Low cumulus.

Division into species (principle—the general outline or extension).

Ice cloud.—High level, 20,000 to 27,000 feet:
Cirrus. (1) Fiber.
(2) Streamer.
(3) Plume.
(4) Wisp.
Cirro-stratus. (5) Band.
(6) Bar.
(7) Patch.
(8) Veil.
Cirro-cumulus. (9) Cirro-cumulus pellets.
(10) Cirro-cumulus balls.

Water cloud.—Central level, 12,000 to 15,000 feet:
Alto-stratus. (11) Gauze.
(12) Band.
(13) Patch.
(14) Cover.
Alto-cumulus. (15) Alto-cumulus balls.
(16) Alto-cumulus plates.

Water cloud.—Lower level, 2000 to 6000 feet:
Stratus. (17) Sheet.
(18) Cover.
Cumulus. (19) Woolpack.
(20) Mountain.
(21) Roll-cumulus.
(22) Strato-cumulus.
(23) Wrack.
(24) Fog.

From the above it is apparent that clouds may be naturally and exhaustively divided into species on the principle of general outline. There are, however, differentiations of species constituting varieties, which, though easily and generally overlooked, are of the very greatest import, since every turn in a staple form must have a corresponding cause in the combination of weather factors that produced it; and it is here that we depart on new lines. What others have heretofore designated trifles, that we now take up, suspecting them to contain the very knowledge we are after.

Differentiations (constituting varieties) may be observed in:
(*a*). The general outline.
(*b*). The surface.
(*c*). The organization.

OUTLINE.	SURFACE.	ORGANIZATION.
Hooked.	Undulating.	Flaky.
Bent.	Drifted.	Granulated.
Branched.	Banked.	Lumpy.
Pectinate.	Warped.	Watery.
Screwed.	Rippled:	Fibrous.
	(*a*) Plain.	
	(*b*) With interference.	
Curved.	Furrowed.	Marbled.
Tangled.	Striated:	
	(*a*) Lengthwise.	
	(*b*) Across.	
	(*c*) Obliquely.	
Headed:		
(*a*) Forward.		
(*b*) Backward.		
Wispy.		
Tapering.		
Feathery.		
Fleecy.		
Fringed.		

A combination of one of these adjectives with one of the names in the list of species makes it possible to perfectly designate and register a large number of staple cloud forms.

Certain storm clouds are so independent and so well organized that special terms are required to fully describe them. They exhibit peculiar developments, which I will call processes.

1. Mammæ.
2. Antlers.
3. Beards.
4. Trailers.
5. Fringe.

The well-developed thundercloud shows some or all of the following processes:
At top: (1) Beak (forward).
(2) Spur (rear).
Below: (1) Ram (front).
(2) Rudder (rear).

[4] Lehrbuch, p. 263. [Germ. Ed.]

These four, when they occur combined together, have long ago suggested the name of anvil cloud. Besides this classical form I may mention:

1. Cloud wedge.
2. Crescent.
3. Funnel.
4. Umbrella cloud.

Thus far I have made use of form only and have shown that all clouds may be fully described according to a uniform principle. But it is not the form only which has its story to tell; on the contrary, form tells but half the history of the cloud. If we desire to derive all the information possible we must take in the accidentals. These may be grouped under the following heads:

1. Condition.
2. Motion.
3. Distribution.
4. Color.

Condition:

1. Well defined. } Species or varities.
2. Ill defined. }
3. Stable.
4. Forming.
5. Breaking up.
6. In transformation: From—to.

Motion:

1. Slow.
2. Rapid.
3. Average.
4. Boiling.
5. End on.
6. Broad side on.
7. Aslant.
8. Direction whence.

Distribution:

1. Isolated.
2. Scattered.
3. Flocked.
4. Aligned.
5. Radiate.
6. Continuous.
7. Coalescing.

Color:

1. White.
2. Gray.
3. Blackish.
4. Red.
5. Yellow.
6. Green.
7. Iridescent, with.... as prevailing color.

The program of a single cloud observation will be, as follows: We are to determine, (1) the species and variety; (2) processes; (3) conditions; (4) elements of motion; (5) distribution; (6) color; (7) configuration of isobars.

The answers to the first six points are entered by means of symbolic signs in one column of a journal, and in a column parallel to this are to be entered the configuration of isobars, together with the state of the weather. Regarding the configuration of isobars, it is evident that most attention must be paid to that system under whose control the observer happens to be at the time of observation. The final and crowning work will be the collating of the two columns. These will in the course of time show repetitions, regularly recurring associations of cloud forms and type of weather, and *such regular associations are the expression of a law of nature:* they will form laws for the forecaster. By such method only shall we reach any practical results in cloud study. In way of consolation for those who find this method too elaborate or too difficult, I will quote a few lines from Clement Ley.[5]

> All said then, and done, the land of clouds is not entirely one of fancy. The art of distinguishing and of usefully employing the distinctions between the varieties of cloud is not nearly so difficult as many an art in which the amateur engages himself for the sake of amusement, and a very cursory acquaintance with the labors of many writers—especially, if it is not insidious to say this of German and American writers—satisfies every one as to the fact that there is also a science of nephology, nascent though this science may be. How can practise and knowledge be most successfully promoted?

To this question, as put by Mr. Ley, I would answer: By systematic and detailed cloud observations; by attending to the so-called *trifles.*

I might enter into some very interesting details myself, but since it is my object to show that cloud study, as a scientific branch of meteorology, is something more than noting one of 10 cloud forms opposite a given date, but I will close, hoping that some of the readers of the REVIEW will interest themselves in one of nature's most interesting languages and lend a helping hand in interpreting it and teaching it to others.

[5] Cloudland, p. 201.

METHODS OF FORECASTING THE WEATHER.

A Lecture delivered by Prof. Dr. J. M. Pernter to the Association for the Advancement of Scientific Knowledge, Vienna, January 14, 1903. Translated from the Vorträge des Vereines zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien. 43d Jahrgang, Heft 14.

Allow me to-day to address you once again on the subject of weather prophets, and this time to bring before you not only one or two kinds of weather forecasting, but to give you a more general survey of all methods at present in use, be they right or wrong, with or without results. I will keep strictly to the title of this lecture and give the prominent place to the methods of forecasting. I shall explain them and subject them to critical analysis, naming at the same time the advocates of each of the various methods; in the technical investigation, we have to do with the value of the methods and not that of the persons. I must, however, at once bring prominently forward the fact that we have at present, unfortunately, no method by which we can forecast the weather with absolute certainty even for one day in advance, to say nothing of longer periods. This is already self-evident from the fact that we are now able to speak of many methods of forecasting, whereas if there were a sure and infallible method, then it would be out of place to speak of the other methods to this society for the advancement of scientific knowledge.

All methods of weather forecasting, not excepting those in use by the central meteorological offices, are based upon observed weather conditions and have, therefore, an empirical foundation. Many of them do not even make the slightest attempt to put their methods on a theoretical basis and content themselves with setting up "weather rules." Even the scientific methods of professional meteorologists have not yet succeeded in deducing a theory capable of determining in advance the changes of the weather as the effect of one or several known causes. Only the advocates of the influence of the moon have ventured solely by means of aprioristic theories to "calculate" the weather for long periods in advance.

There are many widely different methods by which the various classes and kinds of weather prophets carry on the work of weather forecasting. There are those who make use of the behavior of animals to foretell the weather; hunters who recognize the character of the approaching season from the actions of the wild animals; the observers of birds, spiders, crickets, ants, and other animals from whose conduct they judge of the approaching weather. But in addition to this class which utilizes living animals there is another opposing class that prefers to make use of the dead substances of the animal or vegetable kingdoms, such as hairs, strings of instruments, roots and fibers of plants; by means of their expansions or contractions, either with the aid of little weather houses and figures or without them, they recognize the coming weather. Others prefer to consult stones and walls as to the character of the weather to be expected, and turn rather to inorganic nature in order to learn from the "sweating" or dryness of these whether to expect rain or continued fine weather. Thus, as you see, all the kingdoms of nature are drawn upon to furnish prognostics of the weather, and it may depend upon the occupations and predilections of the various persons interested in the coming weather whether they give the preference to one or the other. But I had almost forgotten to mention another class—perhaps the largest—those who are not to be satisfied by any one of the three kingdoms nor even by all three together, and who rely only on